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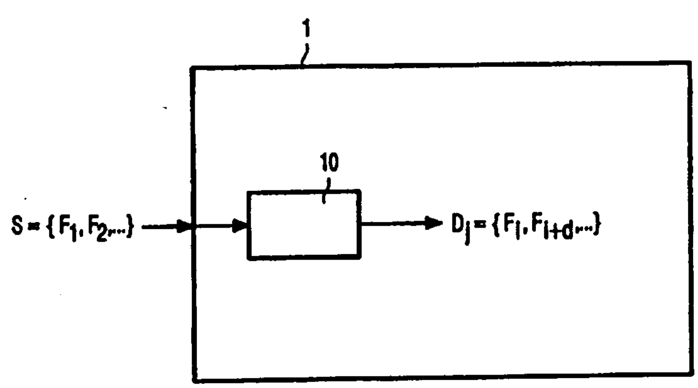

(57) Abstract

Method of detecting a watermark embedded in a signal (S), in which a plurality of frames ({F_1, F_2, ...) of the signal (S) is combined to a detection set (D_j) for one detection event. According to the invention, the reliability of watermark detection is enhanced by using non-consecutive frames ({F_i, F_{i+d}, ...) to form the detection set (D_j). The invention also relates to an apparatus (2) for recording and/or playback of a signal, and to a system for broadcast monitoring, comprising such a watermark detector (24).

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Watermark detection.

The invention relates to a method and a device for detecting a watermark embedded in a signal in which method a plurality of frames of the signal is combined to a detection set for one detection event.

The invention also relates to an apparatus for recording and/or playback of a signal and to a system for monitoring a broadcast signal.

Watermarks are imperceptible or hardly perceptible marks embedded in a signal such as audio, still pictures, animations, video, etc. They are embedded in the signal in such a way that they are difficult to remove. A watermark may comprise additional information such as, for example, information about the source or the copyright status of documents or audiovisual programs. Watermarks allow tracing of piracy and support the protection of intellectual property.

A known method of detecting a watermark comprises a correlation step for correlating the signal with locally stored watermarks. The result of such a correlation is subsequently evaluated. When the correlation of the signal with a given watermark is, for example, larger than a given threshold value, this watermark may be considered to be the watermark embedded in the signal. A correlation with many different watermarks may also be performed, with the watermark having the highest correlation being considered as the watermark that has been used.

Since the signal may be subjected to various signal operations such as MPEG compression, DA/AD conversion, NTSC/PAL conversion, as well as cropping and scaling, a detection based on single frames is often unreliable in the sense that it leads to many missed detections. The article "On the Reliability of Detecting Electronic Watermarks in Digital Images" by A.A.C. Kalker, G.F.C. Depovere and J.P.M. Linnartz, published in the *Proceedings of Eusipco 1998* (Rhodes, Greece) gives a plausible explanation for the fact that the combination of a plurality of frames, for example n, to a detection set enhances the reliability of the detection process by a factor of $\sqrt{n}$. However, this applies only to n uncorrelated frames. It is common practice to combine consecutive frames. However, these are generally highly correlated.

It is an object of the invention to enhance the reliability of detecting a watermark.

To this end, the invention is characterized in that, for forming the detection set, at least one frame is used which does not immediately follow an other frame in the signal, which other frame is also used for the detection set. The use of frames for a detection set other than only consecutive frames has the advantage that it enhances the reliability of detecting a watermark. The reason is that frames which are mutually further apart are generally less correlated. When using less correlated frames, the enhancement of the reliability as applies to uncorrelated frames, namely the reliability of the detection process increasing by a factor of $\sqrt{n}$, is better approximated. The use of frames, not all of which occur consecutively in the signal, is referred to as interleaving.

In an embodiment, the method is characterized in that a predetermined number of frames is used for the detection set, which frames are present in the signal at a mutually predetermined distance corresponding to an integral number of frames. This uniform mode of selecting frames for a detection set is a method which is easily applicable.

In a further embodiment, the predetermined number of frames and the predetermined distance are chosen to be such that their greatest common divisor equals one. In this case, a uniform distribution of I, B and P frames across the various detection sets is achieved for an MPEG signal.

The embodiment as defined in claim 4 is mainly important for an MPEG signal. Also in this case, a uniform distribution of I, B and P frames across the various detection sets is achieved for an MPEG signal.

Further embodiments relate to an apparatus for recording and/or playback of a signal, comprising a device for detecting a watermark according to the invention, and to a system for monitoring a broadcast signal, comprising such a device.

These and other aspects are apparent from and will be elucidated, by way of non-limitative example, with reference to the embodiment(s) described hereinafter.

In the drawings:

Fig. 1 shows an embodiment of a device according to the invention,

Fig. 2 shows an embodiment of an apparatus comprising a device for detecting a watermark according to the invention.

Both Figures only show the elements of the device in so far as is necessary for understanding the invention.

Fig. 1 shows a device 1 for detecting a watermark according to the invention, comprising means 10 for combining a plurality of frames $\{F_1, F_2, \ldots\}$ of a signal S to a detection set D_j for one detection event.

According to the invention, at least one frame F_{i+d} for forming the detection set is used, which frame does not immediately follow another frame F_i, also used for the detection set, in the signal S. One or more intermediate frames are skipped in this way and used for, for example, another detection set. An advantage of using frames $\{F_i, F_{i+d}, \ldots\}$, not all of which are consecutive, is that the frames are mutually less correlated, thus enhancing the reliability of detecting a watermark.

Let it be assumed that a number of n frames $\{F_i, F_{i+d}, \ldots\}$ is used for a detection set D_j. If all consecutive frames $\{F_1, F_2, \ldots\}$ are used as is already known, the first decision moment occurs after n frames. A consequence of using n frames $\{F_i, F_{i+d}, \ldots\}$, not all of which are consecutive, is that the decision occurs at a later moment.

The combination of frames $\{F_i, F_{i+d}, \ldots\}$, not all of which are consecutively present in the signal S, may of course be effected in many different ways. Two interleaving schemes are discussed by way of example. Within the scope of the invention, it is possible to use different schemes yielding comparable results.

The first scheme to be discussed is uniform interleaving. In this form of interleaving, the shortest distance between two frames $\{F_i, F_{i+d}, \ldots\}$ used for the detection set D_j is equal to a constant value d in the signal, corresponding to an integral number of frames of the signal. This may be expressed as follows

$$F_i \in D_j \Leftrightarrow i \equiv j \pmod{d}$$

A total number of frames $\{F_1, F_2, \ldots\}$ equal to d times n is assigned to a number of detection sets D_j equal to d. As an example, the detection sets D_j are shown below with a number of frames $n = 12$ and a mutual distance $d = 5$.

$$\begin{aligned}
D_1 &= \{F_1, F_6, F_{11}, F_{16}, F_{21}, F_{26}, F_{31}, F_{36}, F_{41}, F_{46}, F_{51}, F_{56}\},\\
D_2 &= \{F_2, F_7, F_{12}, F_{17}, F_{22}, F_{27}, F_{32}, F_{37}, F_{42}, F_{47}, F_{52}, F_{57}\},\\
D_3 &= \{F_3, F_8, F_{13}, F_{18}, F_{23}, F_{28}, F_{33}, F_{38}, F_{43}, F_{48}, F_{53}, F_{58}\},\\
D_4 &= \{F_4, F_9, F_{14}, F_{19}, F_{24}, F_{29}, F_{34}, F_{39}, F_{44}, F_{49}, F_{54}, F_{59}\},\\
D_5 &= \{F_5, F_{10}, F_{15}, F_{20}, F_{25}, F_{30}, F_{35}, F_{40}, F_{45}, F_{50}, F_{55}, F_{60}\}
\end{aligned}$$

For the sake of clarity, this distribution is illustrated with reference to Table I. Table I shows the numbers of the frames $\{F_1, F_2, \ldots\}$ consecutively, as occur in the signal S

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60

Table I: Illustration of uniform interleaving, $n = 12$, $d = 5$.

The consecutive frames $\{F_1, F_2, \ldots\}$ of the signal S are shown as d series of n frames. This does not need to be a physical separation of the frames $\{F_1, F_2, \ldots\}$ of the signal, although this is possible, but may also be considered to be a conceptual notion so as to elucidate the invention. The different fonts indicate that the frames $\{F_1, F_2, \ldots\}$ are used in different detection sets D_j. A detection set D_j comprises frames $\{F_i, F_{i+d}, \ldots\}$ with the numbers indicated by the same font in Table I. With this form of interleaving, the first detection decision takes place after $d(n-1)+1$ frames. The process is repeated after dn frames.

It is important for many applications that the watermark survives a compression such as, for example, MPEG. The different frames in an MPEG signal: I, B and P frames may behave differently as regards survival of a watermark. When using uniform interleaving, there may be a problem for some values of n and d. For the purpose of illustration, an example is given with $n = 12$ which, in this case, is also a Group of Picture (GOP) size of an MPEG signal S. The distance between the frames is $d = 4$. The distribution of the frames $\{F_i, F_{i+d}, \ldots\}$ is shown in Table II.

I	B	B	P	B	B	P	B	B	P	B	B
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48

Table II: Illustration of uniform interleaving, $n = 12$, $d = 4$ at MPEG.

As is evident from Table II, the different detection sets D_j comprise a non-uniform distribution of MPEG frames. For example, all I frames occur in one detection set D_j. Solutions within the scope of the invention are possible for a more uniform distribution of I, B and P frames across the detection sets D_j.

When using uniform interleaving, it is, for example, possible to choose *n* and *d* in such a way that their greatest common divisor equals one. This is, for example, the case for $n = 12$ and $d = 5$, as already discussed hereinbefore. See Table III.

I	B	B	P	B	B	P	B	B	P	B	B
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60

Table III: Illustration of uniform interleaving, $n = 12$, $d = 5$ at MPEG.

It can clearly be seen that each detection set D_j comprises a frame from each column. This means that each type of frame occurs in each detection set D_j.

It is further possible, for example, to make the uniform interval more flexible. This may be effected, for example, by means of diagonal interleaving. With *n* being an integral number of times a GOP size of an MPEG signal S, a uniform distribution of I, B and P frames is achieved with the expression for diagonal interleaving, which may be defined as follows:

$$F_i \in D_j \Leftrightarrow i \equiv 1 + (j-1)n + m(n+1) \pmod{dn} \text{ voor } m \in \{0, 1, \ldots, n-1\}$$

For $n = 12$ and $d = 5$, the following detection sets D_j are obtained.

$$D_1 = \{F_1, F_6, F_{11}, F_{14}, F_{19}, F_{24}, F_{27}, F_{32}, F_{40}, F_{45}, F_{53}, F_{58}\},$$
$$D_2 = \{F_5, F_{10}, F_{13}, F_{18}, F_{23}, F_{26}, F_{31}, F_{36}, F_{44}, F_{47}, F_{52}, F_{57}\},$$
$$D_3 = \{F_4, F_9, F_{17}, F_{22}, F_{25}, F_{30}, F_{35}, F_{38}, F_{43}, F_{48}, F_{51}, F_{56}\},$$
$$D_4 = \{F_3, F_8, F_{16}, F_{21}, F_{29}, F_{34}, F_{37}, F_{42}, F_{47}, F_{50}, F_{55}, F_{60}\},$$
$$D_5 = \{F_2, F_7, F_{12}, F_{15}, F_{20}, F_{28}, F_{33}, F_{41}, F_{46}, F_{49}, F_{54}, F_{59}\}$$

The distribution of the frames $\{F_i, F_{i+d}, \ldots\}$ is shown in Table IV.

I	B	B	P	B	B	P	B	B	P	B	B
1	**2**	*3*	4	5	6	**7**	*8*	9	10	11	**12**
13	14	**15**	*16*	17	18	19	**20**	*21*	22	23	24
25	26	27	**28**	*29*	30	31	32	**33**	*34*	35	36
37	38	39	40	**41**	*42*	43	44	45	**46**	*47*	48
49	*50*	51	52	53	**54**	*55*	56	57	58	**59**	*60*

Table IV: Illustration of diagonal interleaving, $n = 12$, $d = 5$.

As already explained hereinbefore, the consecutive frames $\{F_1, F_2, \ldots\}$ of the signal S are shown as d series of n frames. The number of frames per series is equal to the number of frames in a detection set, namely n. In this case, this number is further equal to an integral number of times the GOP size of an MPEG signal S. It is evident from Table IV that the position in the signal S of a frame F_i used in a detection set D_j shifts in each subsequent series by one position with respect to the start of the series. With respect to this frame F_i, which is here referred to as reference frame for the sake of simplicity, the other frames F_{i+d} for the same detection set D_j are present in the same series at a distance which is equal to an integral number of times the number of series d. It may be noted that the average and most frequently occurring distance between the frames $\{F_i, F_{i+d}, \ldots\}$ in a detection set D_j equals $d = 5$, alternated by other distances such as 3 and 8 in this example.

Fig. 2 shows an apparatus, for example a DVD player 2, comprising means 21 for reading a DVD disc so as to obtain a DVD signal S. The DVD signal S is an MPEG bit stream which is stored on the DVD disc. The DVD signal S is applied from an output 23 of the DVD player 2 via a switch 22. The output 23 is connected to an external MPEG decoder and a picture display device (not shown). For, for example, copyright protection it is assumed that the DVD player 2 cannot play video signals S with a predetermined watermark, unless other conditions are met which are not important for the invention. Watermarked signals S may be played back only when, for example, the disc comprises a given "wobble" key. To be able to detect a watermark, the DVD player 2 comprises a watermark detector 24 which is adapted as described with reference to Fig. 1. The watermark detector 24 receives the stored signal S and controls the switch 22 in dependence upon the detected watermark.

The invention may be further used, inter alia, in a system for broadcast monitoring. Broadcasts may be coded in advance with a watermark identifier. Monitoring television broadcasts with a system comprising a watermark detector 24 provides a mechanism for intellectual property protection and statistic data collection.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention. Those skilled in the art will be able to conceive alternative embodiments without departing from the scope of the appended claims.

Reference numerals between parentheses in the claims have been incorporated to elucidate these claims and should not be construed as limiting the claim. The word "comprising", and derivatives thereof do not exclude the existence of elements or steps other than those defined in a claim. The invention may be implemented by separate elements and by a correctly programmed computer. In the claims relating to a product, in which several means are mentioned, several of these means may be implemented in one and the same piece of hardware.

In summary, a method of detecting a watermark embedded in a signal S is described, in which a plurality of frames $\{F_1, F_2, \ldots\}$ of the signal S is combined to a detection set D_j for one detection event. According to the invention, the reliability of watermark detection is enhanced by using non-consecutive frames $\{F_i, F_{i+d}, \ldots\}$ to form a detection set D_j. The invention also relates to an apparatus for recording and/or playback of a signal, and to a system for broadcast monitoring, comprising such a watermark detector.

CLAIMS:

1. A method of detecting a watermark embedded in a signal (S), in which method a plurality of frames $\{F_1, F_2, ...\}$ of the signal (S) is combined to a detection set (D_j) for one detection event,

characterized in that, for forming the detection set (D_j), at least one frame (F_{i+d}) is used which does not immediately follow an other frame (F_i) in the signal (S), which other frame (F_i) is also used for the detection set (D_j).

2. A method as claimed in claim 1,

characterized in that a predetermined number of frames ($\{F_i, F_{i+d}, ...\}$) is used for the detection set (D_j), which frames ($\{F_i, F_{i+d}, ...\}$) are present in the signal (S) at a mutually predetermined distance corresponding to an integral number of frames ($\{F_1, F_2, ...\}$).

3. A method as claimed in claim 2,

characterized in that the predetermined number of frames ($\{F_i, F_{i+d}, ...\}$) and the predetermined distance are chosen to be such that their greatest common divisor equals one.

4. A method as claimed in claim 1,

characterized in that a predetermined number of frames ($\{F_i, F_{i+d}, ...\}$) is used for each detection set (D_j) which number of frames ($\{F_i, F_{i+d}, ...\}$) corresponds to an integral number of times a GOP size of an MPEG signal (S),

consecutive frames ($\{F_1, F_2, ...\}$) in the signal (S) being divided into a plurality of series of a number of consecutive frames ($\{F_1, F_2, ...\}$), which number of frames ($\{F_1, F_2, ...\}$), equals the number of frames ($\{F_i, F_{i+d}, ...\}$) in the detection set (D_j),

and a reference frame (F_i) is chosen from each series, the reference frames (F_i) in consecutive series being shifted by one position, calculated from the start of the series,

and the reference frame (F_i) as well as frames (F_{i+d}) present at a distance from the reference frame (F_i) corresponding to an integral number of times the number of series are used for the detection set (D_j).

5. A device (1) for detecting a watermark embedded in a signal (S), the device (1) comprising:

means for receiving the signal (S); and means (10) for combining a plurality of frames $\{F_1, F_2, \dots\}$ of the signal (S) to a detection set (D_j) for one detection event,

characterized in that the means (10) are adapted to use at least one frame (F_{i+d}) which does not immediately follow another frame (F_i), also used for the detection set (D_j), in the signal.

6. An apparatus (2) for recording and/or playback of a signal (S), comprising means (21) for receiving the signal (S);

characterized in that the apparatus (2) further comprises a device (24) as claimed in claim 5 for detecting a watermark embedded in the signal (S).

7. A system for monitoring a broadcast signal (S), comprising means for receiving the signal (S);

characterized in that the system further comprises a device (24) as claimed in claim 5 for detecting a watermark embedded in the broadcast signal (S).

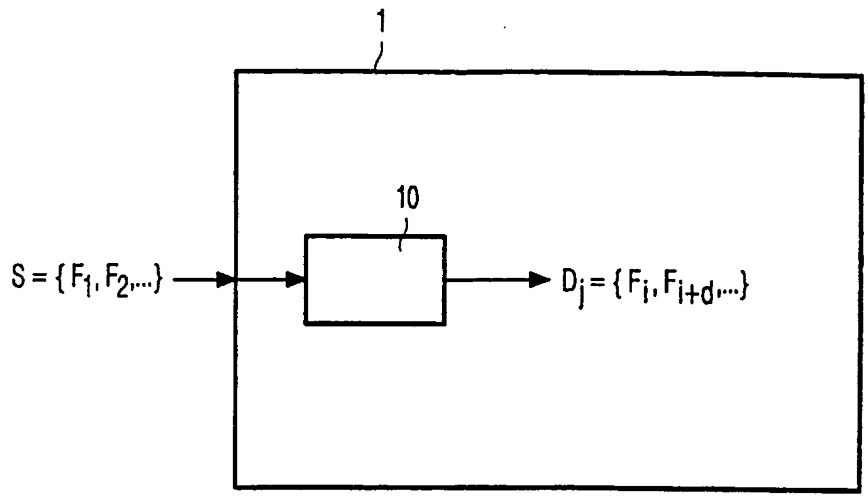

FIG. 1

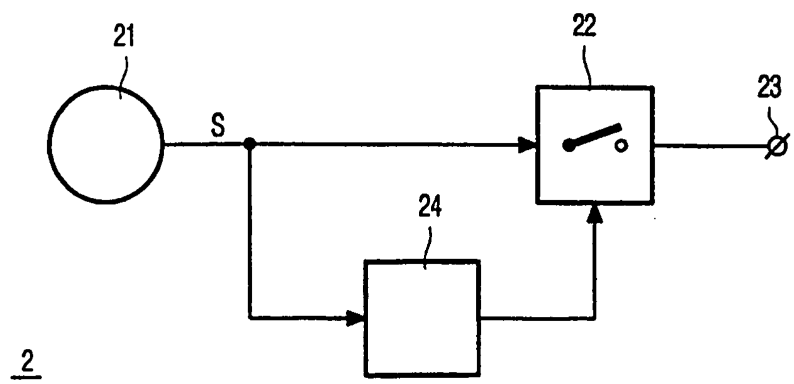

FIG. 2